Review of Effects of Double Crested Cormorants, American White Pelicans, and North American River Otters on Fisheries

Prepared by: Randy Oplinger, Fisheries Experiment Station

Introduction

One goal of fisheries management is to create sustainable lake, stream, and reservoir ecosystems. Angling opportunities are often provided through stocking or through management actions that maximize natural recruitment. Excessive mortality can decrease angler catch rates. Fish mortality can come from a variety of sources including angler harvest, predation, or natural causes (e.g., disease, old age, etc.). Since the 1970's, a significant increase in the populations of double crested cormorants *Phalacrocorax auritus*, American white pelicans *Pelecanus erythrorhyncho*, and North American river otters *Lontra canadensis* have been observed in western North America. All three species feed primarily on fish predators. Anglers have become increasingly concerned about the effects that these organisms are having on fisheries.

In this report, I provide a summary of the literature on the effects of these species on fisheries. I briefly discuss the life history of each species and the range of each species within Utah. I focused on studies that discussed the effects of these species on salmonids. I do, however, provide a brief discussion on the effects of these predators on other fish species. In the process of preparing this summary, I reviewed over 45 papers. These papers are cited at the end of the summary and can be made available on request.

Double Crested Cormorants

Distribution and Life History

There are five recognized subspecies of double crested cormorants. *P. a. auritus* is the most widely distributed subspecies and is the only subspecies that has been documented in the intermountain west. Due to the effects of chlorinated hydrocarbon insecticides (e.g., DDT) cormorant numbers decreased to very low numbers through the 1960's (Price and Weseloh 1986). Federal bans on the use of these insecticides and the passage of the Migratory Bird Treaty Act of 1972 have been attributed to a significant increase in cormorant numbers (Ross and Johnson 1997). In addition, there is some evidence that the over-winter survival of cormorants has benefitted from an increase in the number of aquaculture facilities in the southern United States (Wires and Cuthbert 2006).

Considerable information on the distribution and abundance of cormorants is available from Wyoming. The first cormorant breeding pair was documented on Yellowstone Lake in 1928 (Findholt 1988). By 1983 there were 629 nesting pairs and that number increased to 1477 pairs by 1986 (Findholt 1988). Breeding colonies can be found through much of Wyoming (Findholt 1988). Little current information regarding the distribution of double crested cormorants in Utah is available. Mitchell (1977) provides a map documenting the distribution of cormorants in Utah during the 1970's. At that time, cormorants were found around the Great Salt Lake, Utah Lake, and Bear Lake. Additional populations were documented near Fillmore and Logan. Cormorant numbers were at reduced levels at the time that the Mitchell (1977) report was published. A study published nearly two decades later documented the presences of double crested cormorants on 12 of 13 reservoirs surveyed in the southwestern portion of the State (Ottenbacher et al. 1994). No information regarding the current distribution of cormorants was found, however, Christmas Bird Counts (Audubon Society 2012) seem to suggest that numbers of cormorants in Utah have increased since 1994. From 1995 to 2003, 1-2 cormorants were detected statewide during these annual counts (<0.02 cormorants/hr of observation effort). Since 2004, numbers of observed cormorants increased, peaking at 38 (0.49 cormorants/hr of observation effort). These Christmas Bird Counts underestimate abundance since cormorants do not typically overwinter in Utah (Ottenbacher et al. 1994). Abundances are greater in the summer, still, these Christmas Bird Counts provide an indication of increased cormorant numbers within the State. Studies have evaluated factors that influence cormorant density. Simmonds et al. (1997) studied cormorant populations on eight reservoirs in Oklahoma. In general, cormorant density was positively correlated with reservoir surface area, drainage basin size, and forage density. Cormorant density was negatively correlated with boat ramp density (a measure of human disturbance; Simmonds et al. 1997). The authors found no cormorants on the study reservoirs during the summer and when the reservoirs were frozen.

Cormorants dive underwater to feed and are known to be excellent swimmers. The maximum depth that cormorants have been documented to dive is 35 m below the surface, although, they typically feed at depths < 10 m (Gremillet et al. 2006). They are opportunistic feeders. Fish, amphibians, insects, crayfish, and occasionally small mammals have been documented in their diet (Gremillet et al. 2006). Cormorants nest in their summer range. They are build nests out of sticks. The nests can be perched in a tree or can be set on the ground. Both parents tend for the eggs and young. Nests are typically constructed near water bodies since regurgitated fish are a major component of the diet of chicks. In Utah in 1988 and 1989, cormorants were documented to construct nests in cottonwood groves at both Piute and Minersville Reservoirs (Ottenbach et al. 1994). The nests at Minersville Reservoir were not successful in either year (Ottenbach et al. 1994). It is almost certain that cormorants nest at other sites in Utah, however, since the species is poorly studied in the State, these sites have not been thoroughly documented.

Effects of Cormorants on Fisheries

Many anglers consider cormorants as a threat to their fishing opportunities (Ottenbacher et al. 1994, Simmonds et al. 1997). Generally, research has shown that cormorants do consume sport fish, but, their consumption is less than what is assumed by anglers (Simmonds et al. 1997). Research in Mississippi has shown that the total fish consumption of adult cormorants averages 504 g/bird/day (Glahn and Brugger 1995). Studies in Florida, however, have demonstrated lower consumption rates (225 g/bird/day; Schramm et al. 1987). Regardless, the effects of cormorants on fisheries vary, but in certain circumstances, can be significant. In most instances, the consensus is that the numbers of fish consumed by cormorants is not excessive and is comparable to the numbers of fish harvested by anglers. The impacts of cormorants on sport fishes appear to be greatest on smaller water lakes or reservoirs and in systems that are dominated by sport fish and contain few alternative prey species (Trapp et al. 1997). Cormorants appear to be non-selective predators and at times can consume large numbers of fish shortly after stocking (e.g., Modde et al. 1996, Derby and Lovvorn 1997). Double crested cormorants have consumed significant numbers of cultured channel catfish *Ictalurus punctarus* in the southern United States (Stickley et al. 1992). Significant effects on salmonid production facilities has not been documented (Pitt and Conover 1996).

Trapp et al. (1997) reviewed data from 25 studies that the evaluated the effects of cormorants on fish populations. Their data indicates that cormorants are opportunistic feeders that tend to feed on the most abundant species in a system. Interestingly, however, they found that salmonids tended to be present in diets half as frequently as expected. This study also included the results from a survey that was sent to the directors of the fish and wildlife agency from each state. A total of 25 states (not including Utah) responded. The majority of the agencies were concerned about the effects of cormorants within their states, but, none of the agencies reported any firm evidence for cormorants causing depletion of sport fish stocks.

Despite the thoroughness of the literature review by Trapp et al. (1997), there are several more recent studies that were not included. In the late 1990's considerable research was conducted on cormorant predation in eastern Lake Ontario. Research on this lake revealed that salmonids and bass constituted <2% of the diet of cormorants (Ross and Johnson 1997). The primary constituent of the cormorant diet on this lake were alewife *Alosa pseudoharengus* (42.7%; Ross and Johnson 1997). Panfish (34.0%) and yellow perch *Perca flavescens* (18.4%) were also major constituents. In a companion study (Ross and Johnson 1999), the consumption of brown trout *Salmo trutta* and lake trout *Salvelinus namaycush* by cormorants was evaluated for a four day period after stocking fingerling from each species. During that four day window, it was estimated that 0.5% of the stocked brown trout were lost due to cormorant predation and that no lake trout were consumed by the cormorants. Barge stocking (vs. bank stocking) of fish reduced cormorant induced mortality. Diana et al. (2006) studied the effects of cormorants on yellow perch in Lake Huron and found that cormorants accounted for < 6.3% of the total yellow perch mortality in the lake. Belyea et al. 1997 estimated that annually, that cormorants consume 2.3% of the yellow perch biomass in Lake Huron (1.8% removed by anglers). Fielder (2008) found that cormorants were a major factor causing the decline of yellow perch populations off the Les Cheneaux Islands, Lake Huron. On Oneida Lake, New York, cormorants were estimated to consume 1.1% of the walleye *Sander vitreus* biomass per year and to consume 7.7% of the yellow perch biomass (Rudstam et al. 2004). Cormorants were implicated as a contributing factor to the decline of walleye and yellow perch in the lake (Rudstam et al. 2004).

The literature has also documented the effects of cormorants on riverine ecosystems. Derby and Lovvorn (1997) studied the effects of cormorant predation on fishes in the North Platte River, Wyoming. They found that suckers constituted 85% of the mass of the diets of cormorants prior to salmonid stocking. After stocking, salmonids made up 98% of the mass of the diets of the cormorants. The study estimated that 80% of the stocked fish were consumed by birds (cormorants and pelicans). Collis et al.

(2001) tracked the numbers of steelhead *Oncorhynchus mykiss* and Chinook salmon *Oncorhynchus tshawytscha* consumed by cormorants and Caspian terns *Sterna caspia* on one island in the Columbia River. The authors estimated that this single bird colony consumed 15% of the hatchery released steelhead into the river and 2% of the salmon. Cormorants were responsible for 28% of the total predation by this colony.

In addition to the research that has been performed in the Great Lakes and the Columbia River, the effects of cormorant predation on smaller reservoir fisheries has been studied. Teuscher et al. (2005) estimated that 30% of the hatchery raised rainbow trout fingerling released into Blackfoot Reservoir, Idaho were consumed by birds (cormorants and pelicans) within the first week after stocking. The lengths of the fish consumed by the cormorants ranged from 50-300 mm TL. Simmonds et al. (2000) modeled the effects of cormorant predation on sport fish populations from eight Oklahoma reservoirs. They estimated annually that cormorant predation reduced angler harvest of channel catfish by 3.1%, largemouth bass *Micropterus salmoides* by 2.9%, and white crappie *Pomoxis annularis* by 1.8%.

The only studies that have been conducted in Utah have been performed on Minersville Reservoir (Modde et al. 1996) and an aggregate of 13 reservoirs in the southwestern portion of the state (Ottenbacher et al. 1994). The purpose of the Minersville Reservoir (Modde et al. 1996) study was to document the extent of predation by double crested cormorants on stocked rainbow trout *Oncorhynchus mykiss* fingerling (274,000 across 3 stockings, mean TL of each stocking ranged from 91-102 mm). The authors directly observed bird behavior and collected cormorant diet information through stomach samples. After applying a model, Modde et al. (1995) estimated that 31.3% of the trout were consumed by cormorants within 2 weeks of stocking. The fingerling were most concentrated near where they were stocked into the reservoir and the cormorants appeared to most concentrated near the stocking site. The numbers of cormorants residing at the reservoir peaked shortly after the fish were stocked. The fingerling constituted 18.9% of the biomass of the cormorants diet and 75% of the diet biomass were subadult trout (Modde et al. 1995). The authors did not determine whether cormorants were selective for trout, however, they noted that Utah chub *Gila atraria* were more abundant in the reservoir numerically than trout. Ottenbacher et al. (1994) performed surveys of cormorants on 13 reservoirs in the southwestern portion of the state. They found cormorants on 12 of the reservoirs. Cormorants were most numerous in the spring and on lower elevation water bodies. Ottenbacher et al. (1994) also noted that cormorants were permanent summer residents on the larger reservoirs (Otter Creek and Piute Reservoirs). Depending on the reservoir, trout constituted 24-81% of the diet of the cormorants. Utah chub constituted the majority of the remainder of the diet.

Beyond the review conducted by Trapp et al. (1997), very little synthesis of the effects of cormorants on fisheries has been presented. Regardless, a few general trends appear in the literature. First, it appears that cormorants focus predation on waters where there are a high density of vulnerable prey. In particular, increases in cormorant numbers have been observed after fish stocking (e.g., Modde et al. 1996, Derby and Lovvorn 1997). This concentration of cormorants can be attributed to an increase in fish numbers. Hatchery reared fish are also more vulnerable to cormorant predation since they have poorer swimming performance, are more surface oriented, and have less experience with predators than their wild counterparts (Bostrom et al. 2009). The effects of cormorants on stream populations has not been studied and significant mortality in streams has not been documented. Cormorants, however, feed by diving underwater (Gremillet et al. 2006). As a result, they may not be adapted to feeding in the shallow, swift water found in streams. Cormorants can, however feed in larger rivers (e.g, Collis et al. 2001). One major limitation of all known cormorant predation studies is that these studies have not evaluated the prey selection habits of cormorants. There is antidotal evidence that cormorants select prey in accordance to the relative abundance of prey species (e.g, Ottenbacher et al. 1994, Ross and Johnson 1997). Prey abundance data was not presented for any study reviewed.

American White Pelican

Distribution and Life History

There are eight species of pelicans in the World. Only two of those species, the brown pelican *P. occidentalis* and the American white pelican are found in North American. The brown pelican is a coastal species and is not found in Utah. The American white pelican is an inland species and can be found within the State. The American white pelican is widely distributed throughout North America. Numbers of American white pelicans are increasing (King and Anderson 2005). It is estimated that between 1980 and 2002 that the pelican population size increased by roughly 5% per year (King and Anderson 2005). Pelicans overwinter in the southern United States and spend the summer in the northern United States and Canada. Pelicans follow two major migration routes (east and west of the continental divide; Anderson and Anderson 2005). Pelicans born in Utah are found along both migration routes (Anderson and Anderson 2005). Little information regarding the distribution of pelicans in Utah has been published. Christmas bird count data has only documented 1-2 American white pelicans in Utah each year since 1990. Therefore, pelicans do not appear to over-winter in Utah. In contrast, it has been estimated that 10-20% of the total American white pelican population nests on the 1 mile long x 0.5 mile wide Gunnison Island which sits in the middle of the Great Salt Lake (Elliott 1992). Therefore, pelicans migrate to Utah for nesting. Birds that nest on Gunnison Island typically travel to the Bear River Migratory Bird Refuge to feed (Elliott 1992). It is assumed that pelicans travel to this island because it is isolated and lacks predators (including humans).

Unlike the double crested cormorant, the American white pelican is a surface feeder. Pelicans primarily consume fish (Anderson 1991). Studies have shown that the average pelican consumes ~400 g fish/day (Schramm et al. 1987). One interesting behavior of the American white pelican is that groups of pelicans often cooperate and surround fish or chase them to the shallows. The most efficient group size has been reported to be four birds (Anderson 1991). Pelicans feed more actively at night than during the day (McMahon and Evans 1992). Pelicans are colonial breeders, nesting in colonies containing up to 5,000 breeding pairs. Nests are shallow depressions in the ground filled with sticks. Breeding typically occurs between April and June.

Effects of Pelicans on Fisheries

The effects of American white pelicans on channel catfish culture are well documented (King 2005). In some situations, the spread of trematode parasites and other diseases by pelicans has a greater impact on catfish culture than direct consumption by the pelicans (King 2005). The effects of pelicans on salmonid culture have not been documented.

Less information regarding the consumption of wild fish by American white pelicans is available. On Yellowstone Lake, pelicans are known to consume adult cutthroat trout *O. clarki* (Stapp and Hayward 2002). It has been estimated that adult pelicans at the lake consume an average of 0.85 kg of fish per day whereas nestlings consume an average of 1.2 kg/d (Stapp and Hayward 2002). Research at Pathfinder Reservoir, Wyoming found that 83% of the biomass consumed by pelicans were common carp *Cyprinus carpio* (Findholt and Anderson 1995). At this reservoir, pelicans typically feed near-shore and only capture prey that are within 1 m of the surface. Although abundant in the reservoir, salmonids were seldom consumed by the pelicans because they typically reside outside the reach of pelicans (Findholt and Anderson 1995). Data from Pathfinder Reservoir suggests that the American white pelican diet composition is more heavily driven by prey vulnerability than abundance (Findholt and Anderson 1995). Studies on the North Platte River, Wyoming indicate that the importance of salmonids to the diet of pelicans increases after stocking (0.1% of mass before stocking and 14% after stocking; Derby and Lovvorn 1997).

The limited information regarding pelican consumption of fish seems to suggest that pelicans can feed on fish in both lentic and deeper lotic systems. The American white pelican appears to feed on salmonids less frequently than cormorants. This difference in diet is driven by differences in the feeding ecology of these two birds. Pelicans only feed on fish that are found within ~1 m of the surface. Pelican consumption of salmonids does appear to increase after stocking.

North American River Otter

Distribution and Life History

The North American river otter is a member of the weasel family that establishes burrows along the shores of lakes and rivers. A study in Idaho showed that home ranges can occupy between 8 and 78 km of stream habitat (Melquist and Hornocker 1983). Dispersing animals have been known to travel 42 km in one day (Melquist and Hornocker 1983). The otter is distributed throughout the western United States and Canada. It can also be found along the eastern sea board into the states surrounding the Gulf of Mexico. It is not found in any Midwestern states. Trapping of otters for the fur trade, water pollution, and destruction of riparian habitat severely depleted otter numbers in the 1800's and early 1900's (Serfass 1988). Formerly, river otters were found in the Midwest but they became extirpated through these activities. In the past 20-30 years, otter numbers have increased. In Utah, otters can be found in Bear River, Colorado River, Green River, Provo River, Raft River, Sevier River, and Weber River basins (UDWR 2010). Between 1989 and 1992, the UDWR imported 63 river otters from out-of-state and planted them in the Green River drainage (UDWR 2010). Colorado has also translocated otters into the Colorado River and it appears that in recent years that otters from Colorado have moved into Utah.

There is no estimate of the size of the river otter population in Utah. Statewide, otters have been observed by biologists more frequently in recent years, suggesting that their numbers are increasing (UDWR 2010). Fewer otters, however, are being observed in the western portion of the State (UDWR 2010).

Effects of Otters on Fisheries

The North American river otter specializes in the consumption of fish (Melquist et al. 1981). It can also consume insects, crayfish, birds, and mammals (Findley et al. 1992). Stearns and Serfass (2011) recovered 569 otter scat samples from the Red River, North Dakota. Fish were found in 83.0% of the samples and crayfish were found in 51.1% of the samples. Insects, birds, amphibians, mammals, and freshwater mussels were also found, albeit, at a lower prevalence rate than fish and crayfish (in 0.2-26.7% of the samples). Of the fish remains found, cyprinids were most abundant, occurring in 64.7% of the scats. Catostomids (13.0% of scats) and centrarchids (11.2% of scats) were the second and third most abundant fish species found (Stearns and Serfass 2011). The mean total length of the fish consumed was 207 ± 50 mm (mean ± SE). Studies on scats from tributaries to Yellowstone Lake have shown that otters rely heavily on spawning cutthroat trout in that system (Crait and Ben-David 2006). River otters typically feed in rivers and streams, however, otters were documented to feed on Yellowstone Lake itself (Crait and Ben-David 2006). Manning (1990) analyzed otter scat in the Mendocino National Forest, California and found fish remains in 89.4% of the samples collected. The majority of the fish found in the samples were salmonids and castosomids. Similarly, Toweill (1974) found fish remains in 80% of scats collected in western Oregon and Roberts et al. (2008) found fish in 86% of scats collected from the Ozarks region of Missouri. Studies on the Green River, Utah found that carp remains in 35.6% of scat samples in trout remains in 22.4% of samples (Findley et al. 1992).

It is well documented that the North American river otter specializes in the consumption of fish. It is generally regarded that otters consume fish in proportion to their availability in the wild (Ryder 1955). Slower moving fish are also preyed on more frequently than faster moving fish (Ryder 1955). For example, catostomids, cyprinids, catfishes, and centrarchids are most frequently reported in the diets of river otters (Toweill 1974; Melquist and Hornocker 1983) Typically, sportfish are not a major component of the diet of otters, except during the spawn (Melquist and Hornocker 1983). One limitation to our understanding of the foraging ecology of the North American river otter is that most of the available diet information is speculative and is based on digested scat samples (Cote et al. 2008). It is well known that otters consume fish, but, further research on the predatory habits and prey selection of otters is needed (Cote et al. 2008).

The effects of otters on fishery "quality" has also not been thoroughly documented. No studies have evaluated the effects of the North American river otter on fisheries. Information regarding the effects of Eurasion otters *Lutra lutra* on fisheries have been documented. Life history differences exist between these two otter species. As a result, inferences regarding river otters that are drawn from studies on Eurasion otters may be questionable (Cote et al. 2008). The Eurasian otter can pose a significant predation issue at fish hatcheries. For example, Kloskowski (2005) interviewed 114 fish farms in Poland and found that otters occurred at 104 of those farms. Of the farms surveyed, 65 reported that otters had historically consumed significant numbers of fish. Among wild populations, Jacobsen (2005) documents the effects of the Eurasion otter *Lutra lutra* on stocked brown trout on two rivers in Denmark. On one river, increased numbers of trout were observed in otter scat samples shortly after the stocking of the trout. On the other river, no increase in trout consumption was observed after fish stocking. Aarestrup et al. (2005) conducted a radio telemetry study on brown trout in Denmark. Of the 50 fish released, 17 tags were found along the banks of the river. The authors speculated that the majority of these 17 were consumed by Eurasian otters.

Data regarding the effects of North American River otters on fisheries is not available. Diet selection and the effects of this species on fisheries should be researched further. Regardless, studies have estimated densities of North American river otters to average one individual per 4-17 km of river habitat (Melquist and Hornocker 1983). The Eurasian otter occurs in higher densities (Melquist and Hornocker 1983). As a result, it is likely that the North American river otter has lesser effects on fisheries than its Eurasian counterpart. The consensus in the literature is that the effects of the North American river otter on fisheries are minimal due to this low population density (Melquist and Hornocker 1983). With that said, female otters live with their pups. On average, otters may have a low population density, but, their density is greater when a family group is present. Thus, it is possible that river otters can have a localized, larger effect on a fishery. Again, more research on the effects of river otters on fisheries is required.

Analysis and Conclusions

The effects of double crested cormorants on fisheries are better documented than the effects of the American white pelican and North American river otter. Studies have shown that cormorants can have a significant influence on large lake, reservoir, and river fisheries throughout the United States. Studies on cormorant predation on fish have been conducted on reservoirs in Utah and surrounding states (Idaho and Wyoming). Cormorants are a non-selective predator that feed on fish in accordance to their relative abundance. Since cormorants dive, they are able to capture prey at a range of depths. Cormorants tend to select smaller prey, but, stocked, catchable sized salmonids are a size that can be easily consumed by cormorants. There is evidence that cormorants travel to reservoirs where there is abundant, easy to capture prey. Increases in cormorant numbers have been documented at reservoirs shortly after stocking. Cormorants can also consume significant numbers of stocked fish (up to 80% of fingerling stocked; Derby and Lovvorn 1997). Research on the Great Lakes has demonstrated that nighttime and barge stocking can reduce cormorant predation on hatchery fish (Ross and Johnson 1999).

Pelicans can also significantly influence fisheries. Unlike cormorants, pelicans do not dive to capture prey. As a result, pelicans only prey on fish that are near the surface and consequently, pelican diet composition is primarily driven by the presence of vulnerable prey rather than overall prey abundance. Pelicans do not typically prey heavily on salmonids, but, trout can be a major prey item shortly after stocking. It has been speculated that this occurs because stocked trout typically reside near the surface.

In contrast, the effects of North American river otters on fisheries is less studied. Fish are a major component of the diet of otters. Otters, however, typically prey on fish that are easily captured and salmonids appear to be a minor component of the diet of otters. It is possible that otter densities are low enough to prevent them from significantly affecting a fishery.

Populations of all three predator species are expanding. Consequently, the effect of these predators on fisheries is expected to increase in the future. One major limitation of the research on these species is that diet composition studies have not been performed in conjunction with prey abundance studies. Until these two components are studied simultaneously, it will be difficult to determine whether these predators are truly focusing their predation efforts on species that are of interest to fisheries managers.

Literature Cited

Aarestrup, K., N. Jepsen, A. Koed, and S. Pedersen. 2005. Movement and mortality of stocked brown trout in a stream. Journal of Fish Biology 66: 721-728.

Anderson, J. G. T. 1991. Foraging behavior of the American white pelican (*Pelecanus erythrorhynchos*) in western Nevada. Colonial Waterbirds 14:166–172.

Anderson, J. G. T., and K. B. Anderson. 2005. An analysis of band returns of the American white pelican, 1922-1981. Waterbirds 28: 55-60.

Audubon Society. 2012. Annual Christmas bird count results. Retrieved April 19, 2012 from http://netapp.audubon.org/cbcobservation/Historical/SpeciesData.aspx.

Belyea, G. Y., S. L. Maruca, J. S. Diana, P. J. Schneeberger, S. J. Scott, R. D. Clark, J. P. Ludwig, and C. L. Summer. 1997. Impact of double-crested cormorant predation on the yellow perch population in the Les Cheneaux Islands of Michigan. Symposium on Double-Crested Cormorants: Population Status and Management Issues in the Midwest. Retrieved April 23, 2012 from http://digitalcommons.unl.edu/nwrccormorants/6.

Boström, M. K., S.-G. Lunneryd, L. Karlsson, and B. Ragnarsson. 2009. Cormorant impact on trout (*Salmo trutta*) and salmon (*Salmo salar*) migrating from the river Dalälven emerging in the Baltic Sea. Fisheries Research 98:16–21.

Collis, K., D. D. Roby, D. P. Craig, B. A. Ryan, and R. D. Ledgerwood. 2001. Colonial waterbird predation on juvenile salmonids tagged with passive integrated transponders in the Columbia River estuary: vulnerability of different salmonid species, stocks, and rearing types. Transactions of the American Fisheries Society 130:385–396.

Cote, D., H. M. J. Stewart, R. S. Gregory, J. Gosse, J. J. Reynolds, G. B. Stenson, and E. H. Miller. 2008. Prey selection by marine-coastal river otters (*Lontra canadensis*) in Newfoundland, Canada. Journal of Mammalogy 89:1001–1011.

Crait, J. R., and M. Ben-David. 2006. River otters in Yellowstone Lake depend on a declining cutthroat trout population. Journal of Mammalogy 87:485–494.

Derby, C. E., and J. R. Lovvorn. 1997. Predation on fish by cormorants and pelicans in a cold-water river: a field and modeling study. Canadian Journal of Fisheries and Aquatic Sciences 54:1480–1493.

Diana, J. S., S. Maruca, and B. Low. 2006. Do increasing cormorant populations threaten sportfishes in the great lakes? A case study in Lake Huron. Great Lakes Research 32: 306-320.

Elliott, A. 1992. American White Pelican. *In:* del Hoyo, Josep; Elliott, Andrew & Sargatal, Jordi (eds.): *Handbook of Birds of the World* (Vol. 1: Ostrich to Ducks): 310, plate 20. Lynx Editions, Barcelona.

Fielder, D. G. 2008. Examination of factors contributing to the decline of the yellow perch population and fishery in Les Cheneaux Islands, Lake Huron, with emphasis on the role of double-crested cormorants. Great Lakes Research 34: 506-523.

Findholt, S. L. 1988. Status, distribution and habitat affinities of double-crested cormorant nesting colonies in Wyoming. Colonial Waterbirds 11:245–251.

Findholt, S. L., and S. H. Anderson. 1995. Diet and prey use patterns of the American white pelican (*Pelecaus erythrorhynchos*) nesting at Pathfinder Reservoir, Wyoming. Colonial Waterbirds 18:58–68.

Findley, W. R. 1992. The reintroduction of river otter to the Green River, Utah: Progress Report III. Brigham Young University.

Glahn, J. F., and K. E. Brugger. 1995. The impact of double-crested cormorants on the Mississippi delta catfish industry: a bioenergetics model. Colonial Waterbirds 18: 168-175.

Grémillet, D., M. Enstipp, M. Boudiffa, and H. Liu. 2006. Do cormorants injure fish without eating them? An underwater video study. Marine Biology 148:1081–1087.

Jacobsen, L. 2005. Otter (*Lutra lutra*) predation on stocked brown trout (*Salmo trutta*) in two Danish lowland rivers. Ecology of Freshwater Fish 14, 14:59–68.

King, D. T. 2005. Interactions between the American white pelican and aquaculture in the southeastern United States: an overview. Waterbirds 28: 83-86.

King, D. T., and D. W. Anderson. 2005. Recent population status of the American white pelican: a continental perspective. Waterbirds 28: 48-54.

Kloskowski, J. 2005. Otter *Lutra lutra* damage at farmed fisheries in southeastern Poland, I: an interview survey. Wildlife Biology 11:201–206.

Manning, T. 1990. Summer feeding habits of river otter (*Lutra canadensis*) on the Medocino National Forest, California. Northwestern Naturalist 71:38–42.

McMahon, B. F., and R. M. Evans. 1992. Nocturnal feeding in the American white pelican. The Condor 94: 101-109.

Melquist, W. E, J. S. Whitman, and M. G. Hornocker. 1981. Resource partitioning and coexistence of sympatric mink and river otter populations. Worldwide Furbearer Conference 1:187-220.

Melquist, W. E., and Hornocker, M. G. 1983. Ecology of river otter in West Central Idaho. Wildlife Monographs. 83. The Wildlife Society, Inc. 60pp.

Mitchell, R. M. 1977. Breeding biology of the double-crested cormorant on Utah Lake. Western North American Naturalist 37: 1-23.

Modde, T., A. F. Wasowicz, and D. K. Hepworth. 1996. Cormorant and grebe predation on rainbow trout stocked in a southern Utah reservoir. North American Journal of Fisheries Management 16:388–394.

Ottenbacher, M. J., D. K. Hepworth, and L. N. Berg. 1994. Observations on double-crested cormorants (*Phalacrocorax auritus*) at sportfishing waters in southwestern Utah. Western North American Naturalist 54:272–286.

Pitt, W. C., and M. R. Conover. 1996. Predation at intermountain west fish hatcheries. The Journal of Wildlife Management 60: 616–624.

Price, I. M., and D. V. Weseloh. 1986. Increased numbers and productivity of double-crested cormorants, *Phalacrocorax auritus* on Lake Ontario. Canadian Field Naturalist 10: 474-482.

Roberts, N. M., C. F. Rabeni, J. S. Stanovick, and D. A. Hamilton. 2008. River otter, *Lontra canadensis* , food habits in the Missouri Ozarks. The Canadian Field-Naturalist 122:303–311.

Ross, R. M., and J. H. Johnson. 1997. Fish losses to double-crested cormorant predation in eastern Lake Ontario, 1992-97. Retrieved April 18, 2012 from http://digitalcommons.unl.edu/nwrccormorants/7.

Ross, R. M., and J. H. Johnson. 1999. Effect of altered salmonid stocking methods on cormorant predation in eastern Lake Ontario. New York State Department of Environmental Conservation Report, February 1, 1999.

Rudstam, L. G., A. J. VanDeValk, C. M. Adams, J. T. H. Coleman, J. L. Forney, and M. E. Richmond. 2004. Cormorant predation and the population dynamics of walleye and yellow perch in Oneida Lake. Ecological Applications 14:149–163.

Ryder, R. A. 1955. Fish predation by the otter in Michigan. Journal of Wildlife Management 19: 497-498.

Schramm, H. L., E. A. Okrah, and M. W. Collopy. 1987. Potential Problems of Bird Predation for Fish Culture in Florida. The Progressive Fish-Culturist 49: 44–49.

Serfass, T. L., R. P. Brooks, J. M. Novak, P. E. Johns, and O. E. Rhodes. 1988. Genetic variation among populations of river otters in North America: Considerations for reintroduction projects. Journal of Mammalogy 79:736–746.

Simmonds, R. L., A. V. Zale, and D. M. Leslie. 1997. Physical and biological factors affecting seasonal double-crested cormorant densities on Oklahoma reservoirs. Colonial Waterbirds 20:31–40.

Simmonds, R. L., A. V. Zale, and D. M. Leslie. 2000. Modeled Effects of Double-Crested Cormorant Predation on Simulated Reservoir Sport and Forage Fish Populations in Oklahoma. North American Journal of Fisheries Management 20:180–191.

Stapp, P., and G. D. Hayward. 2002. Estimates of predator consumption of Yellowstone cutthroat trout (*Oncorhynchus clarki bouvieri*) in Yellowstone Lake. Journal of Freshwater Ecology 17:319–329.

Stickley, A. R., G. L. Warrick, and J. F. Glahn. 1992. Impact of double crested cormorant depredation on catfish farms. Journal of the World Aquaculture Society 23: 192-198.

Stearns, C. R., and T. L. Serfass. 2011. Food habits and fish prey size selection of a newly colonizing population of river otters (*Lontra canadensis*) in eastern North Dakota. American Midland Naturalist 165:169–184.

Tuescher, D., R. Hillyard, and R. Scully. 2005. Estimating bird consumption on fish at Blackfoot Reservoir. Idaho Fish and Game Report 04-20.

Toweill, D. E. 1974. Winter food habits of river otters in western Oregon. Journal of Wildlife Management 38:107–111.

Trapp, J. L., S. J. Lewis, and D. M. Pence. 1997. Double-crested cormorant impacts on sport fish: literature review, agency survey, and strategies. Retrieved April 18, 2012, from http://digitalcommons.unl.edu/nwrccormorants/9.

Utah Division of Wildlife Resources. 2010. Northern river otter management plan v. 2.0, 2010-2020. Utah DWR Publication 10-22.

Wires, L. R., and F. J. Cuthbert. 2006. Historic populations of the double-crested cormorant (*Phalacrocorax auritus*): implications for conservation and management in the 21st century. Waterbirds 29: 9–37